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TECHNICAL REPORT ECOM-00477-2

COMPACT H-F AIRCRAFT ANTENNAS (2-30 Mc)

SEMI-ANNUAL REPORT

By

J. H. HENDERSHOT

and

R. K. THOMAS

FEBRUARY 1966

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, N.J.

CONTRACT DA 28-043-AMC-00477(E)

MARTIN MARIETTA CORPORATION

Martin Company, Baltimore Division

Baltimore, Maryland

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Prepared by

J. H. HENDERSHOT and R. K. THOMAS

MARTIN MARIETTA CORPORATION

MARTIN COMPANY - BALTIMORE DIVISION

BALTIMORE, MARYLAND

For

U. S. ARMY ELECTRONICS COMMAND, FORT MONMOUTH, N. J.

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ABSTRACT

The program effort reported here is concerned with the design and development of a broadband, compact, omnidirectional airborne antenna in the H-F communications range (2 to 30 Mc). The antenna will be used on several U. S. Army aircraft, both fixed and rotary wing.

The antenna element configuration reported here is a loop-type structure intended to induce currents on the airframe for a predominantly vertical polarized system.

All work on the 1/5-scale exploratory development model antennas has been completed. Impedance, pattern and relative gain measurements have been thoroughly investigated. The selected element configuration for the H-F Compact Antenna is a 2-turn grounded loop.

During this interval, the major effort was spent on the gain measurements of 1/5-scale antennas relative to a 3-ft monopole. An element size reduction to a 2-turn loop from an original 4-turn loop was justified from the measured gain data.

The application of ferrite to the H-F antenna has been considered.

Measured field strength of a matched transmitting coil, with and without ferrite material, is presented.

A full-scale breadboard model antenna of the 2-turn loop was fabricated. Preliminary impedance tests were made, and a successful marriage power test with the automatic tuner was performed at the Univac facility.

The test plans for the 1/5-scale exploratory and the full-scale advanced development models were written and delivered during this period.

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ILLUSTRATIONS

CONCEPT

The object of the investigation is to arrive at the design of a coupling element which may be externally mounted on an aircraft in such a fashion that substantial H-F current flow will be induced on the structure. Thus, the aircraft serves as the antenna; the coupler itself is much too small to possess good radiation characteristics in the frequency range under consideration.

The advantages to be derived from this approach, as compared to existing H-F aircraft antennas, are the following:

(1) Small size. The major constraint specified for this antenna, or coupler, is that the maximum dimension must not exceed 2 ft.

(2) Minor structural modification. Excluding the trailing wire antenna, the other types in use are:

(a) Electrical (probe, tail cap, wing cap)

(b) Magnetic (notch)

Both of these involve substantial structural modification, and the antenna cannot be separated from the particular aircraft for which it was designed.

(3) General applicability. This antenna is to be externally mounted, in contrast to the types mentioned above, and, therefore, may be used on a variety of aircraft.

These advantages are not to be realized without some sacrifice in electrical properties. The coupling to the aircraft will not be as good, in general, as that realized by a larger probe or notch, for example, specifically designed for a given aircraft. For best coupling, the electric type must be located in the region of a voltage maximum, corresponding to the airframe extremities. Conversely, the magnetic type must be located near a current maximum, which requires that it not be installed at the ends of the aircraft structure. The magnetic type was chosen since it afforded more flexibility in location, according to the above remarks, and also since voltage breakdown problems are reduced by its use. High current problems are involved, instead, which must be accommodated in the ultimate design.

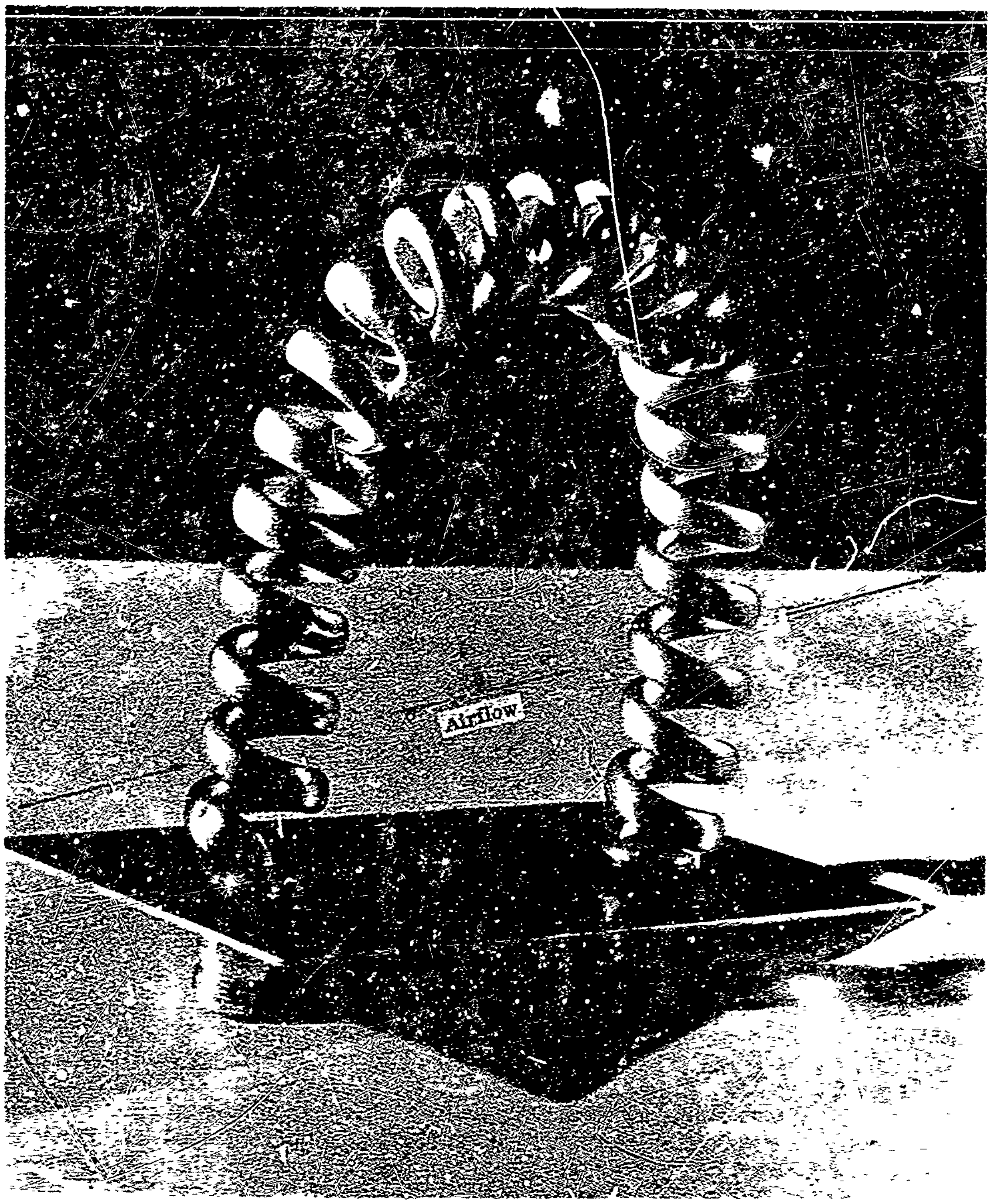

Fig. 1. 1/5-Scale Multiturn Coil Loop Antenna

Element Configurations

During the period, one additional antenna configuration was studied. A 1/5-scale 21-turn coil, shaped into a half-turn grounded loop, is shown in Fig. 1. The primary intent with this configuration was to minimize the drag for a tail installation (preferred location). Pattern measurements indicated good azimuth plane coverage, but still not as optimum as the 4-turn loop. Subsequent gain measurements of this configuration indicated at least a 10-db degradation in relative gain and it was therefore eliminated.

A 2-turn loop, shown in Fig. 2, is now the antenna selected for the H-F compact antenna. Formerly, the 4-turn loop was the chosen configuration: however, calculated aerodynamic loads of greater than 100 lb would exist for a maximum speed of 225 kn. Drag of less than 50 lb for this same speed is anticipated for the 2-turn loop. A full-scale breadboard model of the 2-turn loop is shown in Fig. 3.

Impedance

All impedance measurements have been completed on the 1/5-scale exploratory development model antennas. No significant variations in the impedance parameters were measured for the antenna mounted at the various fuselage and tail locations.

A Smith Chart plot of the impedance characteristics of the 2-turn full-scale breadboard model antenna is shown in Fig. 4. The antenna was mounted on a small metal building, and the Boonton R-X Meter Model 250-A was used for these measurements. At the low frequency end of the band, auxiliary shunt capacitors are employed at the antenna terminals when the test instrument lacks adequate capacity for tuning. Values of parallel resistance and parallel capacitance are recorded at each frequency. An IBM 1620 computer is then used to reduce the data to the series equivalent resistance and reactance components. The main parameter desired from these impedance measurements was the reactance at 2 MHz and, thus, the tuning requirement for the automatic tuner. At 2 MHz, the shunt capacity required for tuning (the antenna is inductive) is approximately 3500 picofarads which is well within the automatic tuner capability of 4200 picofarads. The measured results show that the antenna reactance parameter is inductive from 2 through 25 MHz and capacitive from 25 to 30 MHz. The plot shown is representative of the reactance parameter only, since the antenna relies on the aircraft itself for radiation resistance, especially at the low frequencies.

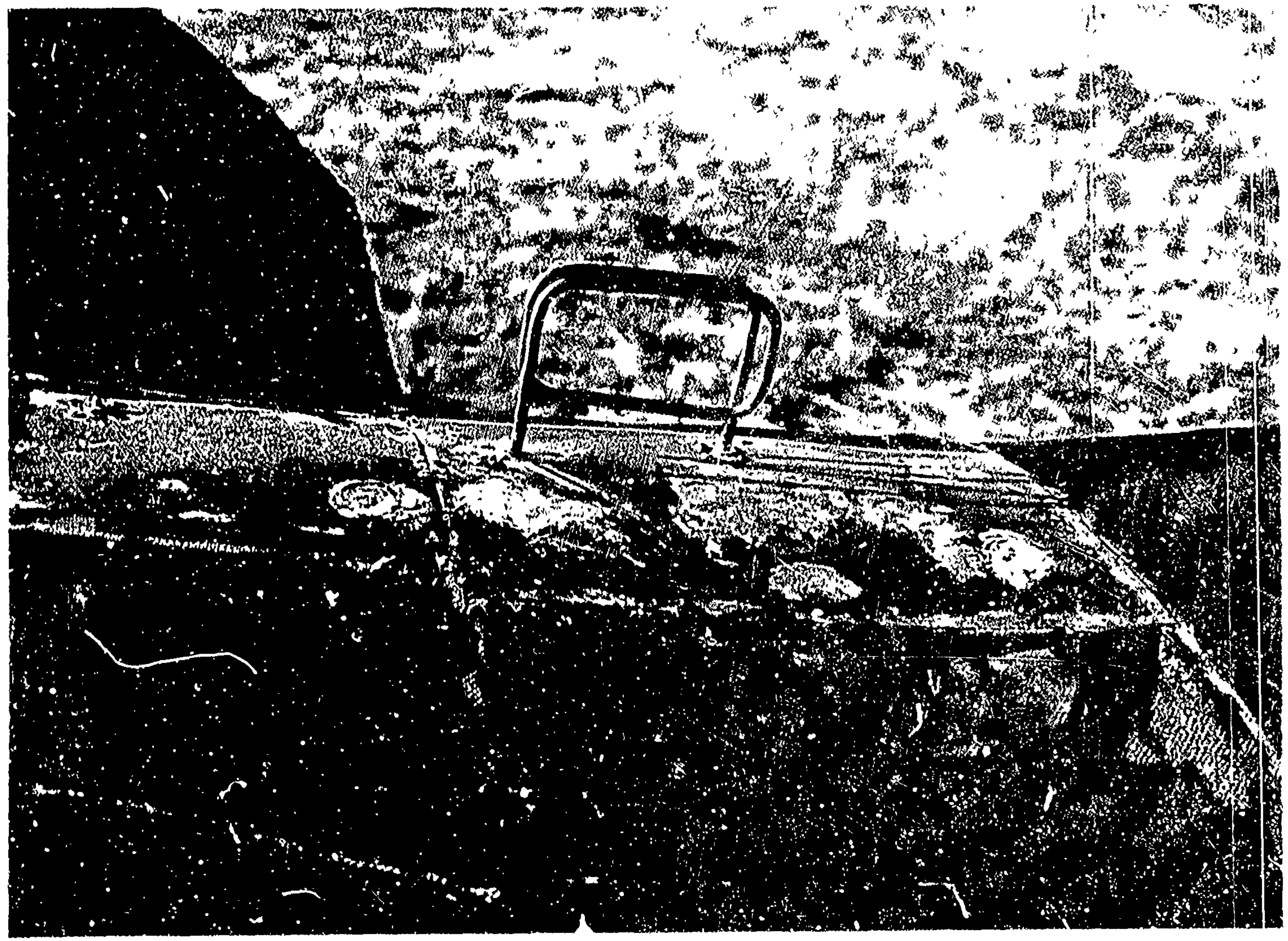

Fig. 2. 1/5-Scale 2-Turn Loop

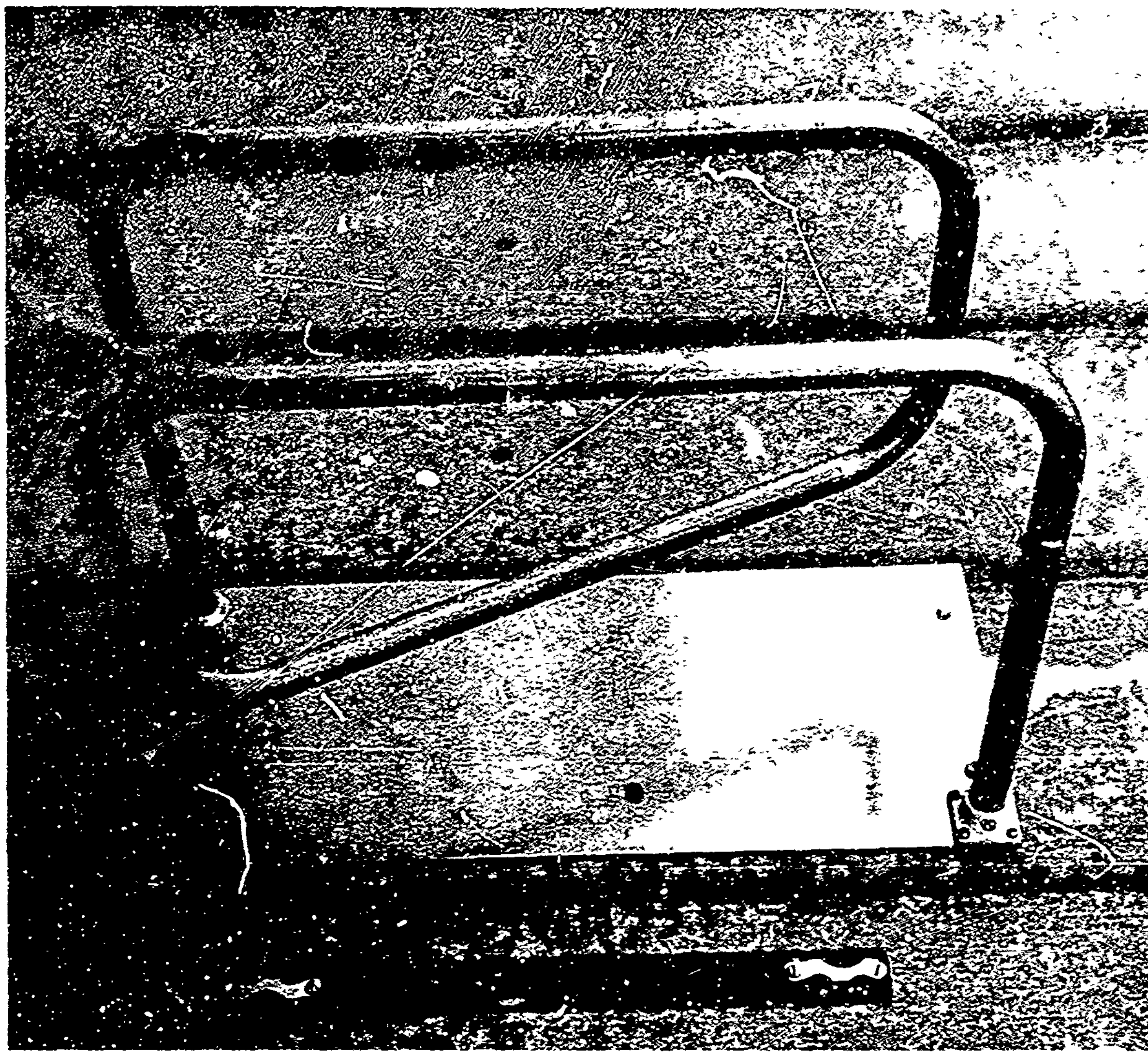

Fig. 3. Full-Scale 2-Turn Loop H-F Antenna

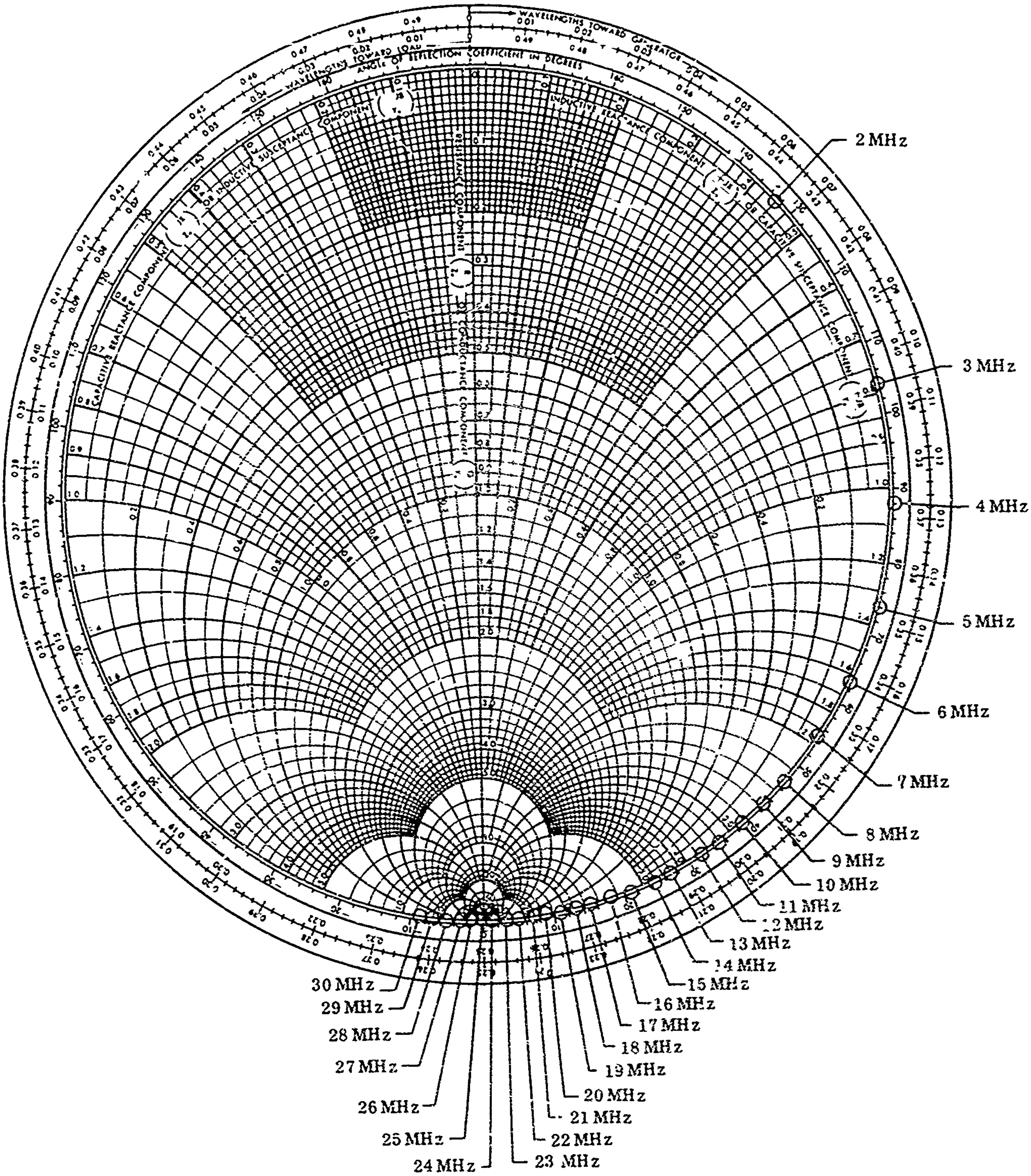

Fig. 4. Full-Scale 2-Turn Loop Impedance Characteristics

Ferrite Investigation

It has been shown by Wheeler* that the radiation power factor of an inductor operating as a small antenna is increased by increasing the relative permeability of its core. Thus, it is of interest to consider this technique for the present application.

It should first be noted that the type of antenna under development involves the radiating properties of the aircraft structure. The extent to which the airframe may be coupled to the feedpoint determines the radiation resistance, and, consequently, the radiation power factor. For an antenna with a maximum dimension of 2 ft. the radiation resistance will be extremely low at a wavelength of 500 ft. such that even if the core permeability were increased several times, the result would still be small in comparison to ohmic losses in the antenna-tuner system. If currents are excited to any degree on a large extent of airframe, however, the effective antenna size is thereby made substantially larger than 2 ft with a consequent increase in effective radiation resistance. Therefore, any means of increasing coupling to the airframe is a step in the right direction.

Currents are induced on the airframe by the changing magnetic field of the inductor antenna. The magnetic field strength will be increased for the same current input by using a high permeability core in the antenna, thus, intensifying the current flow on the airframe. Thus, in concept, this approach appears attractive.

The drawbacks to such a scheme are due to the weight and electrical losses of the magnetic material. In the frequency range under consideration, ferrites are the only materials which do not have prohibitive losses. A sample rod was obtained for investigation from Trans-Tech, Inc., one of the leaders in this field. The material recommended by them as best suited to our requirement from the loss standpoint was a nickel-cobalt ferrite designated TT 2-101, which has a curie temperature of 585° C. With this material, there would obviously be no loss of effectiveness due to heating. Ferrites are, however, temperature sensitive and heating changes would cause detuning which would have to be corrected by the automatic tuning system.

A coil was wrapped around the sample, and relative field strengths were measured in the near field with and without the core sample. The power input was held constant by matching the signal generator output to the two different loads with the manual tuner designed for the exploratory development model antenna. The results are shown in the following table.

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* Wheeler, H. A., "Fundamental Limitations of Small Antennas," Proc, IRE, December 1947, pp 1479 to 1484.

Relative Field Strength

Frequency (MHz)	(With Core/Without Core) ± db
15	+4.5
16	+3.0
17	+4.8
18	+5.0
19	+4.0
20	+3.0
21	+3.6
22	+2.5
23	+3.0
24	+3.0
25	+3.1
26	+3.0
27	+2.8
28	+2.8
29	+3.0
30	+3.0

Insofar as weight is concerned, the specific density of TT-201 is 5.44 gm/cm^3. In order to stay within the 10-lb antenna weight limitation, let us assume that half of the weight could be assigned to ferrite. Five pounds of this material occupies a volume of 25.4 cu in. This is very small compared to the amount required for a 2-ft diameter inductor, so that the effect would be negligible even if there were no losses.

On the basis of the above observations, it is concluded that ferrites have no useful application in this particular antenna development, since the weight required for electrical improvement is prohibitive.

Gain Measurements

Relative gain measurements were performed at two locations of the 1/5-scale Caribou aircraft. The 1/5-scale multiturn loop antenna gain was compared to that of a 3-ft whip from 10 through 150 MHz. For the gain comparison tests, the aircraft was mounted on a rotating turntable to maximize the received signal strength. Thus, the measured gains reported here are for the best aircraft orientation at the particular frequency of interest.

The measured results with the 4-turn grounded loop located atop the fuselage and two orientations are shown in Fig. 5. Peaks in the data occur at 30 and 100 MHz which may be attributed to the physical dimensions of the aircraft model. Gain variations of +2 to -14 db were measured from 10 through 150 MHz. The measured results for two orientations of the 4-turn loop at the mid-tail location of the Caribou are shown in Fig. 6. Gain variations are similar to those for the fuselage location. A more definite orientation preference is noted here for the loop element oriented parallel to the tail. This corresponds to the loop-axis parallel to the tail.

Aerodynamic drag calculations on the 4-turn loop indicated loads of 133 lb for speeds of 225 kn. These loads are almost prohibitive for a tail installation. Additional effort was made to reduce the antenna configuration size and drag while not altering the electrical performance of the antenna. Gain measurements were performed for a reduced height and reduced width (decreasing the number of turns). The measured results shown in Fig. 7 indicate little degradation for a 2-turn loop of reduced height. These results and a reduced drag of less than 40 lb merited an element size reduction. The full-scale equivalent dimensions for the smaller element are shown in Fig. 8.

The basic 2-turn loop H-F compact antenna as envisioned at this time is shown in Fig. 9. The overall dimensions will be 24 x 12 x 17-1/4 in. A fiberglass airfoil shell with foam-fill will enclose the vertical members of the loop as shown for mechanical support and drag reduction. The base plate will be flat and will require an adapter plate to facilitate installation to one of several aircraft. The adapter plate will be used in order to maintain the universality of installation. One end of the loop is grounded to the base plate which provides the elements own ground path while the other end protrudes through the base plate and insulator for connection to the automatic tuner.

Automatic Tuner

The Univac automatic tuner fabrication has been completed and acceptance tests performed at their facility in St. Paul, Minnesota. The Martin 2-turn loop breadboard model and a simulated H-F antenna load by Univac were used for these tests. The tuner performed exceptionally well at all frequencies from 2 to 30 MHz. A matched condition (VSWR 1.6:1) was verified throughout this frequency range. Most of the measurements were performed at 100 w CW input power. At 2 and 30 MHz, the automatic tuner and breadboard antenna were subjected to 400 w CW with no apparent degradation in performance. Some slight heating of 20° to 40° C above ambient temperature was noted at 30 MHz for a continuous power application of about 1-min duration. One significant point in these tests is that the breadboard antenna was tuned out while attached only to a metal bench which provided a poor mockup for a simulated aircraft. Measured output current of 33 amp was noted at 5 MHz while a gradual decrease

to 1 amp at 30 MHz was noted for 100 w input power. At frequencies from 2 to 4 MHz, the current was not measured due to the monitor ammeter limitation of 33 amp. Tuner efficiencies of 80 to 90% were measured from 2 to 9 MHz, while 50% or greater efficiencies were measured from 10 to 30 MHz. The efficiencies were measured on a Univac load that simulated the H-F compact antenna impedance from 2 to 30 MHz.

The efficiency as defined here is the ratio of the measured input average power to the measured output average power $\left(\frac{P_{in}\ avg}{P_{out}\ avg}\right)$. The input power was measured on a M. C. Jones micromatch model MM-252 coupler indicator unit. For the output power measurement, a simulated H-F antenna load consisting of a 5-in. diameter coil with 13 turns was employed. The final 6 turns were shorted with an ammeter and 50-ohm resistor in series to ground. Hence, the measured I^2R values provided an approximate value of the average output power.

The procurement and acceptance of this item are complete, and it will be delivered during the coming interval.

The Collins tunable filter to be utilized in the retransmission mode is still on order and delivery is scheduled during the coming period.

Conclusion

All work on the exploratory model antennas has been completed. The coupling element chosen for the H-F compact antenna is a 2-turn grounded loop.

A flight rated design of the H-F compact antenna is now in progress. This will entail design support from the mechanical, aerodynamic, structural, and dynamic engineers. One test antenna will initially be fabricated and subjected to several environments as part of the qualification testing program. Any changes in design required for these tests will be incorporated in fabrication of the first two flight test antennas. A complete flight test program has been outlined for testing of the H-F compact antennas. After completion of these tests, the changes, if any are required, will be incorporated into the final delivered quantity.

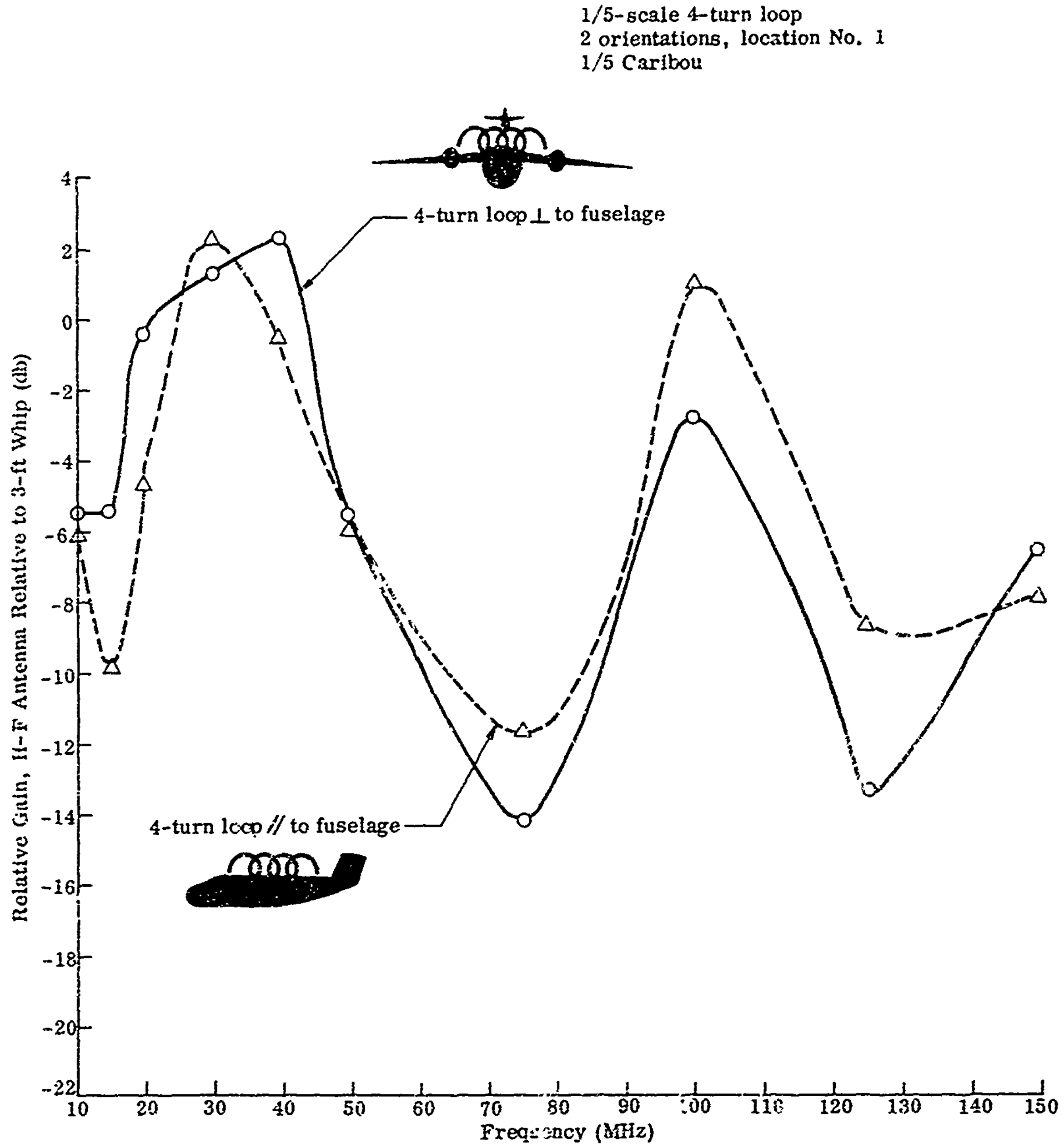

Fig. 5. 4-Turn Loop Gain (H-F antenna/3-ft whip) Versus Frequency

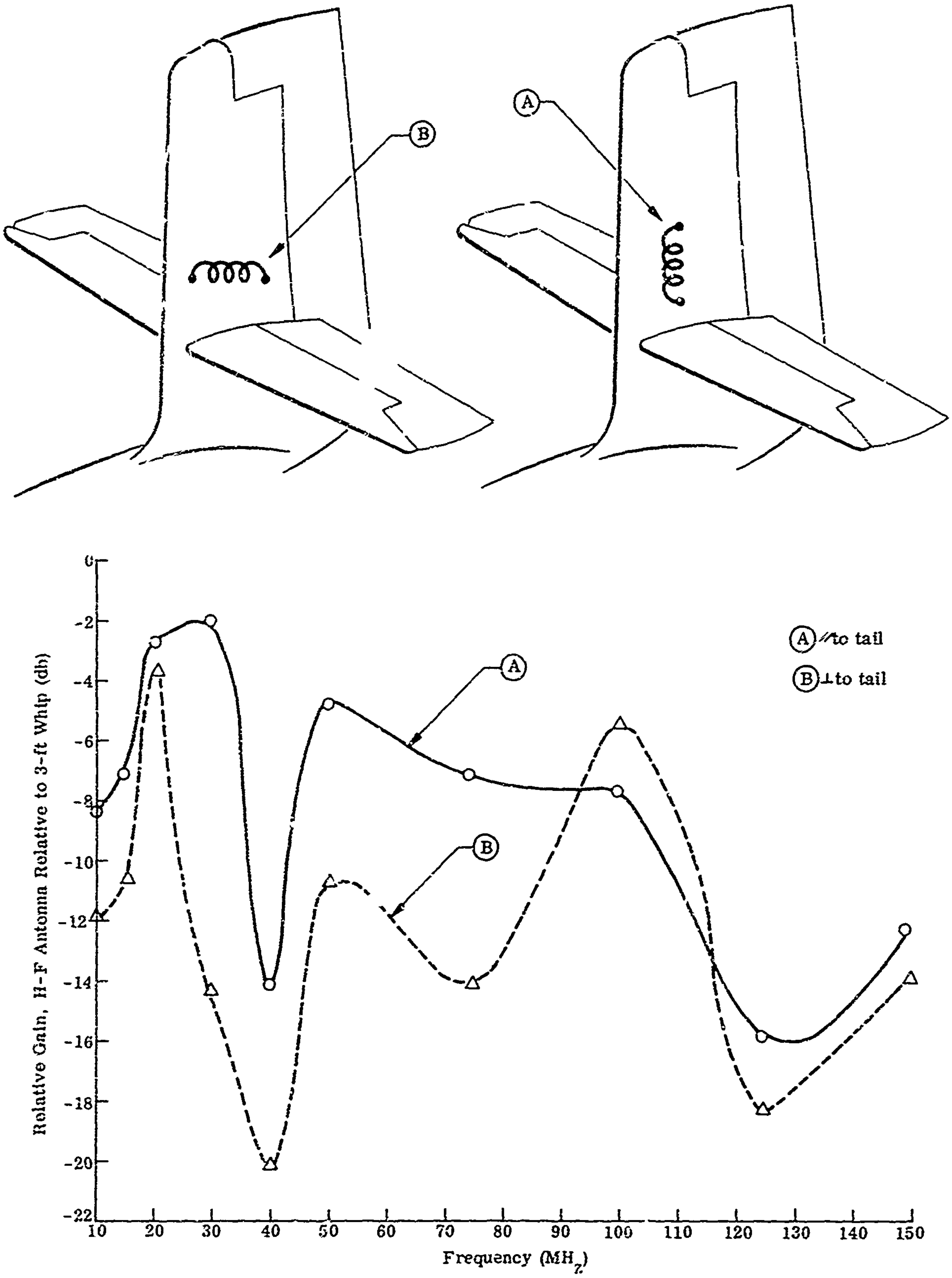

Fig. 6. 4-Turn Loop Mounted on Tail (two orientations) Gain (H-F/whip) Versus Frequency

1/5-scale 4-turn loop mounted across fuselage, location No. 1 on 1/5-scale Caribou

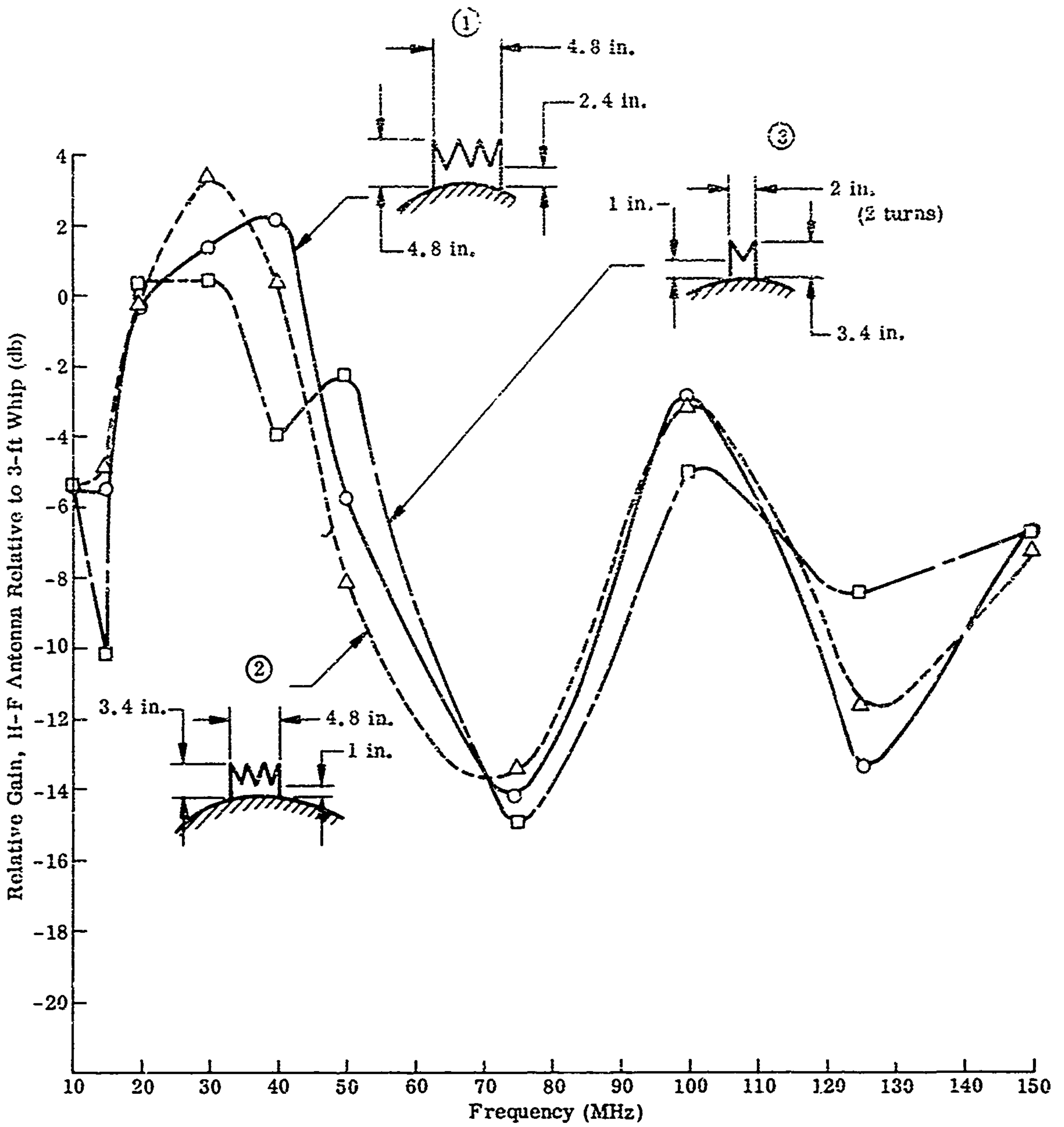

Fig. 7. H-F Antenna Gain (H-F/3-ft whip) as a Function of Size Versus Frequency

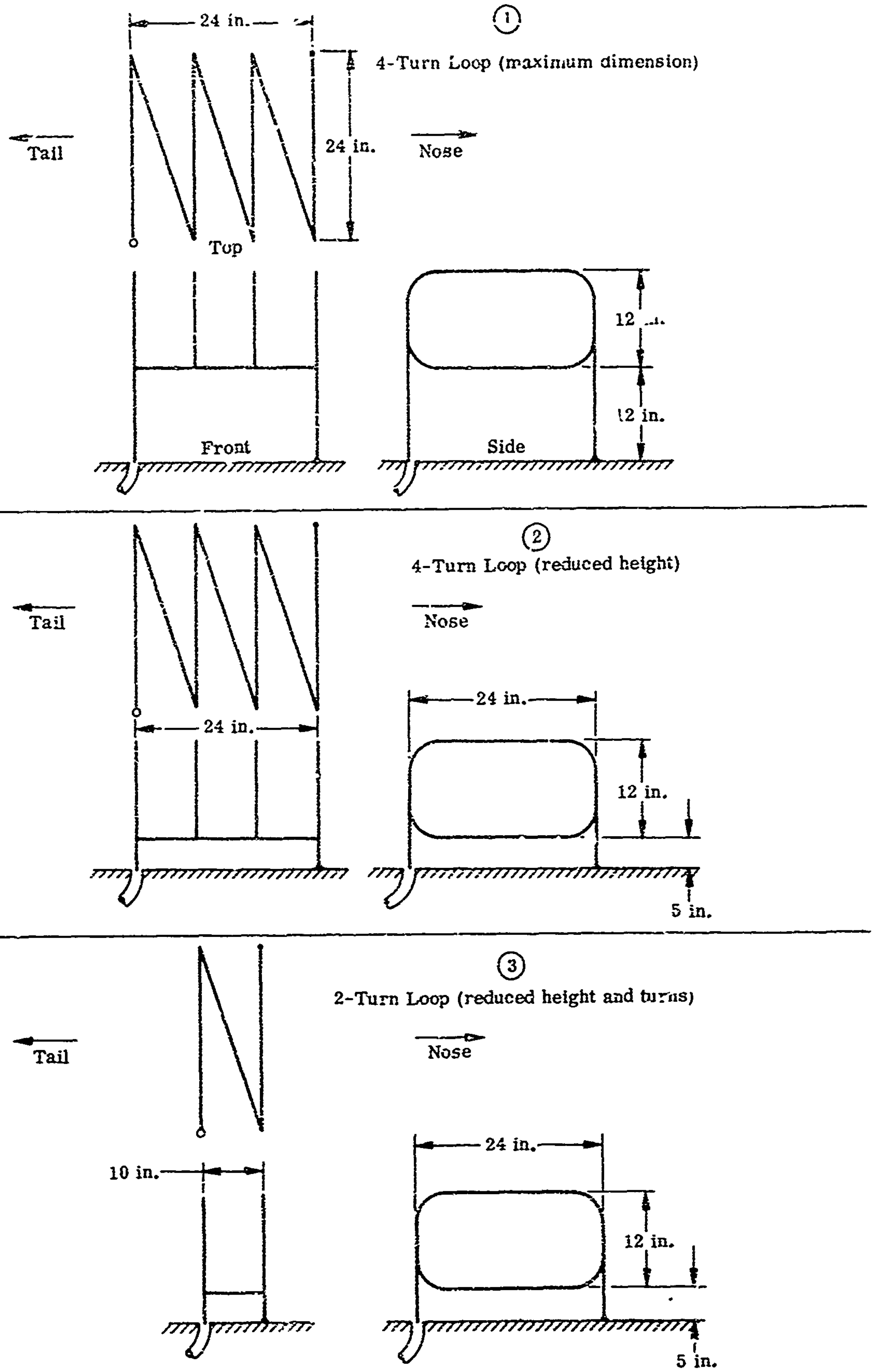

Fig. 8. Evolution of H-F Loop Antenna (refer to Fig. 7)

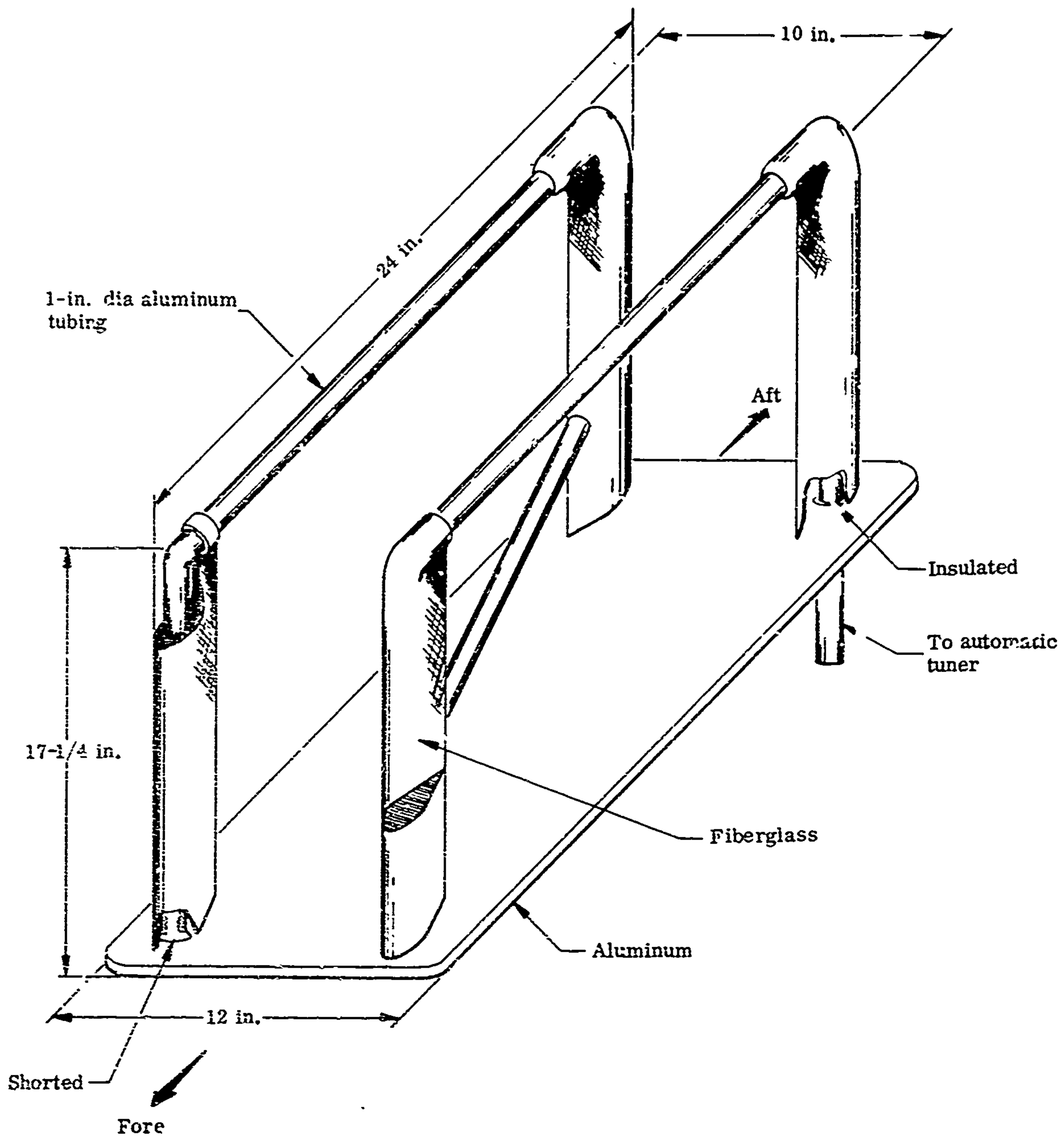

Fig. 9. Full-Scale H-F Compact Antenna

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